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BENDING AND FOCUSING STRUCTURE FOR A CURVED EXTERNAL PROTON BEAM LINE

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This note proposes a lattice structure that may be suitable for the main external beam line. It consists of repeated modules similar to the superperiods of a synchrotron. Each such superperiod contains bending magnets to bend the beam through 7.5 degrees, a long drift space in which to extract part of the beam tangentially to the main beam, and focusing quadrupoles. The extraction envisioned is similar to that of the main ring except that it is done with a vertical electrostatic beam splitter and septum magnet. These split part of the beam off vertically and bend it upwards. After sufficient vertical clearance is achieved the extracted beam is bent back to the horizontal direction.

Each superperiod has 360° of betatron phase advance so that one beam splitter will exactly be imaged on the next one. We have arranged to make the displacement and angle of the beam particles momentum-independent in the extraction region in order to avoid having to steer the beam as different energy components are extracted from the main ring. The vertical β-function is made large (600 meters) at the electric beam splitter to minimize septum loss. The electrostatic septum is followed by over 100 meters of drift space so that particles scattered by the septum can be easily removed by shielding and so that the magnetic septum magnet, having to split an already rather well separated beam, can have large septum thickness, high field, and short length.

The general layout is indicated in Fig. 1 (not to scale). The beam is extracted from the main ring at position 0. Between 0 and 1 the beams betatron ellipses and dispersion functions are brought to values suitable for the beam-line superperiods or sections. Three of these are shown in the figure, labeled A, B, and C, together with three beams splitoff, labeled T_A, T_B, and T_C, which are extracted with the aid of the electric and magnetic septum magnets E and M. The bending magnets are concentrated about the points marked B.

Details of the lattice are shown in Fig. 2. The upper drawing includes a complete superperiod from 1 to 5. It contains two different lattice structures. The interval between 1 and 2 is a so-called π-straight section, while in the shorter interval from 2 to 5 there are two FODO-type cells with 90° phase advance each. The momentum-matching is achieved by distributing the bending symmetrically about points 2 and 5, and it leads to zero dispersion in the spaces ℓ' and L'. By dividing the superperiod in this unequal way we concentrate the bending, which makes the extracted beam separate faster from the main beam. It also results in betatron functions which are very large at E but moderate in the bending magnets.

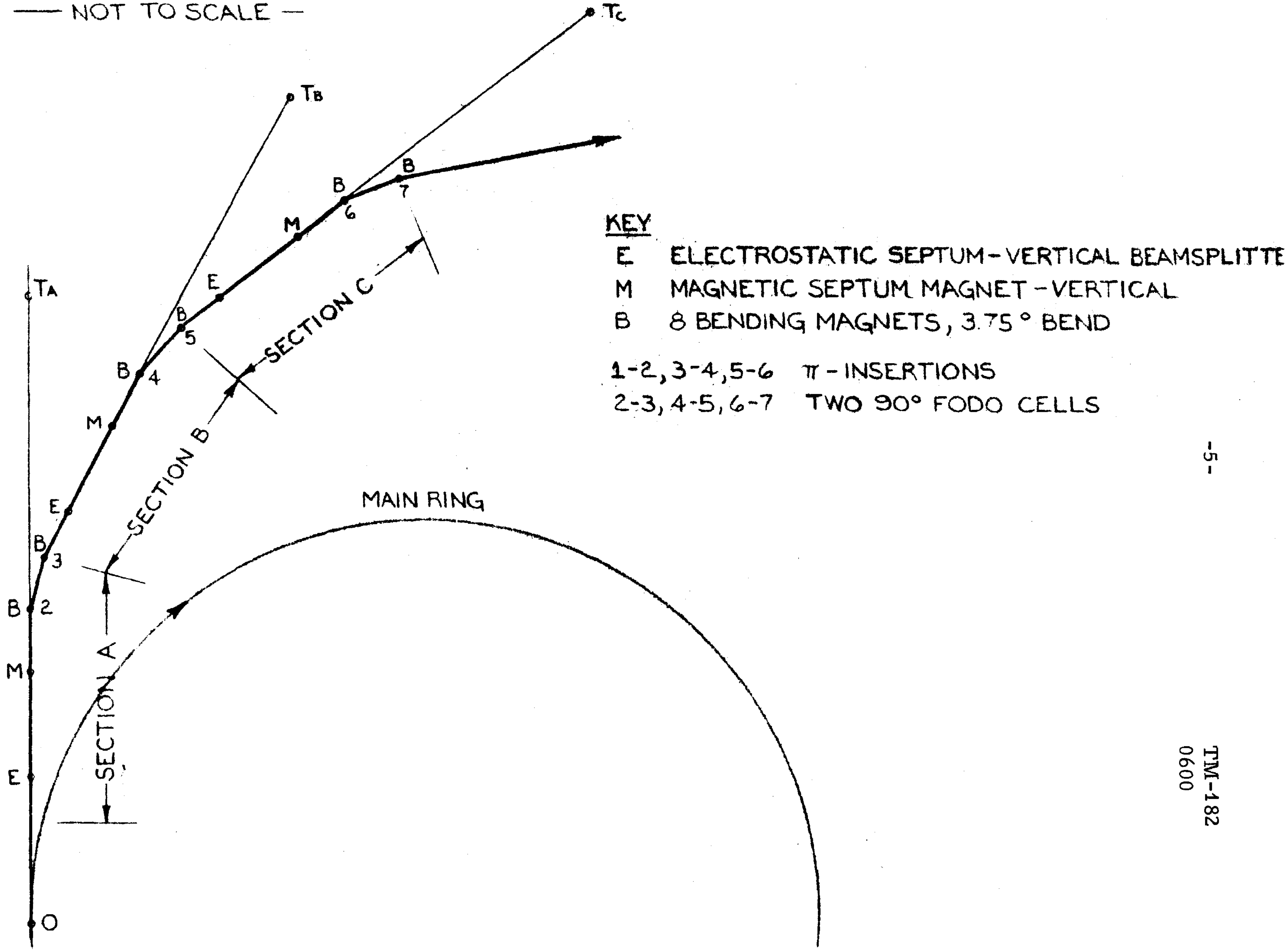
The first superperiod, A, has no bending magnets immediately following point 1. The beam should be delivered from the main ring to this point with zero dispersion, both in displacement and angle, and with beam ellipses matched to the betatron functions of the FODO cell 2-4 at a mid-F position. An unmatched beam would be transmitted by each superperiod so as to reproduce itself from one period to the next, but it would not have zero dispersion and maximum β_γ at the beam splitter or moderate β's in the bending magnets, as desired.

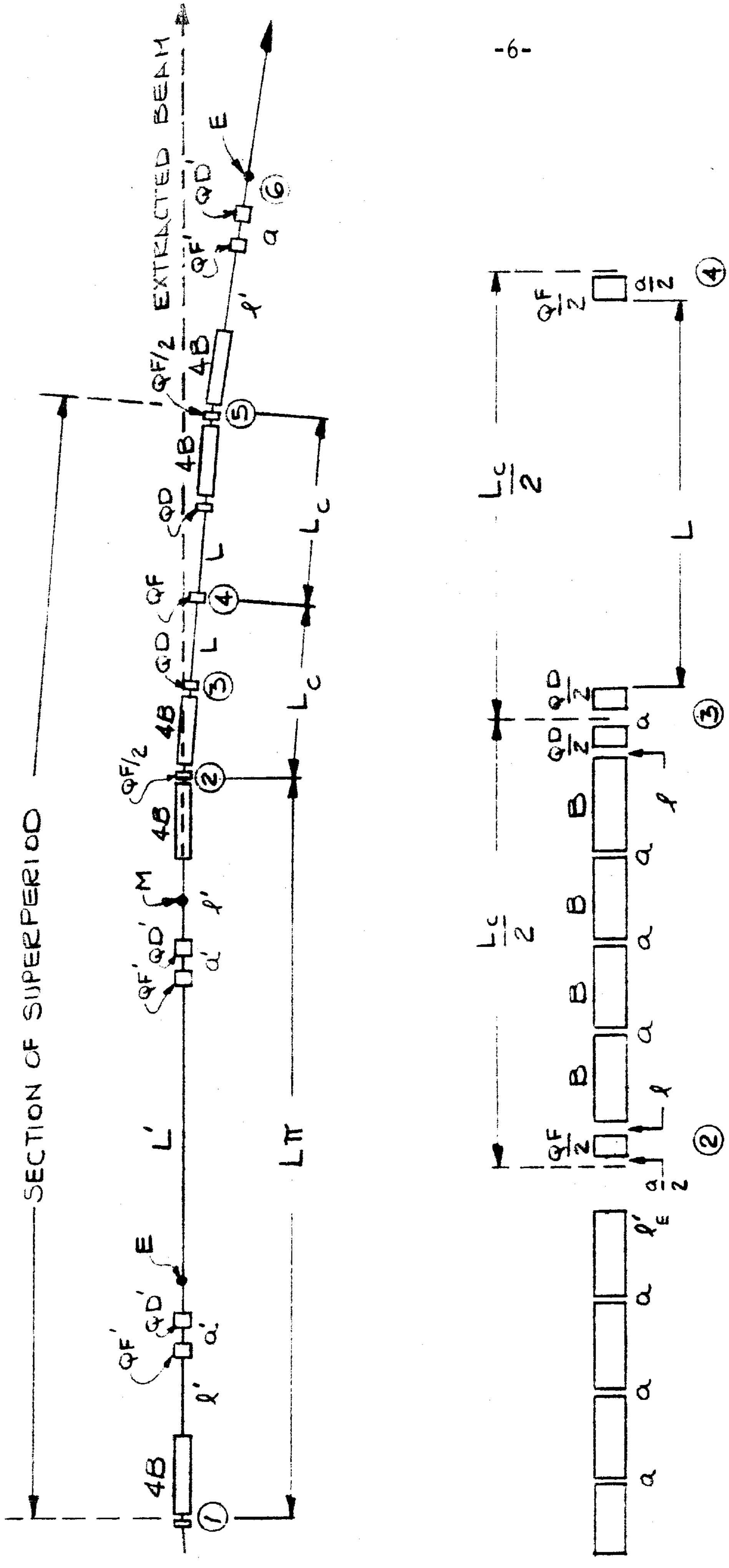
A set of possible parameters for such a system are shown in Table I. Betatron functions were obtained by use of the SYNCH program.

Table I. Bending and Focusing Structure for the External Proton Beam.

Total length of section between beam splitters	Ls	381			m
Total length of π-insertion (1)-(2)	Lπ	261			m
Free length	L'	113.13			m
End length	ℓ'	28.97			m
Short end length	ℓ'e	2.4016			m
Quadrupole separation	a'	8			
Length of π quadrupoles QF', QD'		4.685			m
Total length of cell	Lc	60			m
Lengths of drift spaces	a	0.3048			m
	ℓ	0.92967			m
	L	27.05614			m
Length of quadrupoles QF/2, QD/2		1.31953			m
Length of bending magnet B		6.0706			m
Gradient in QF', QD' (400 GeV)		112.39			kG/m
Gradient in QF/2, QD/2		247.59			kG/m
Bending magnet field		18.02			kG
Bending magnet magnetic radius		742.0			m
Bending angle per section		7.5			deg
Phase advance per section		2π			
Phase advance π-insertion		π			
Phase advance per cell		π/2			
Betatron functions βx, βy, Xp					
Starting at (1)		101	18	0	m
QF'		133	271	0	m
QD'		58	608	0	m
QF'		320	114	0	m
(2), (5)		101	18	-	m
(3)		18	101	-	m
(4)		101	18	5.5	m
(6) approximate		58	606	0	m

FIG. 1
SCHEMATIC OF BEAM LINE
— NOT TO SCALE —





DETAIL OF FODO CELL STRUCTURE

E -- ELECTROSTATIC SEPTUM DEFLECTOR
M -- MAGNETIC SEPTUM MAGNET

FIG. 2